

SPECIFICATION

WASHING MACHINE

5 Technical field

The present invention relates to a washing machine that can treat laundry with antimicrobial treatment using metal ions.

Background art

10 When laundry is washed in a washing machine, it is common to add a treatment substance to water, in particular rinsing water. Common among treatment substances are softening agents and starching agents. In addition, in recent years, there has been a growing demand for treatment whereby laundry is made antimicrobial.

From the hygienic point of view, it is desirable that laundry be hung and dried in the
15 sun. However, in recent years, as more women go to work and more families become nuclear, the number has been increasing of homes where no one is at home during the day time. In such families, there is no choice but to hung and dry laundry indoors. Even in families where someone is at home in the daytime, in wet weather, it is necessary to hung and dry laundry indoors.

20 When laundry is hung and dried indoors, as compared with when it is hung and dried in the sun, bacteria and mold tend to proliferate more easily. This tendency is particularly remarkable when it takes time to dry laundry, for example when the humidity is high as in a rainy season or when the temperature is low. Depending on how bacteria and mold proliferate, laundry may become foul-smelling.

On the other hand, in recent years, there has been an growing sense of thriftiness, encouraging more and more households to recycle the water left in a bath tub after bathing to perform washing. However, bath water, when kept overnight, contains an increased number of bacteria. These bacteria attach to laundry, where they further proliferate and, 5 disadvantageously, produce foul smells.

For these reasons, in households where there is routinely no choice but to hang and dry laundry indoors, there is a strong demand for the antimicrobial treatment of textile articles with a view to suppressing the proliferation of bacteria and mold therein.

Today, many clothes are made from fibers that have previously been subjected to 10 antimicrobial-deodorant treatment or other microbe-restricting treatment. However, it is difficult to arrange for all the textile articles used in a household to be exclusively ones that have previously been subjected to antimicrobial-deodorant treatment. Moreover, as such articles are washed over and over, the effect of the antimicrobial-deodorant treatment wears out.

15 These circumstances have led to the idea of treating laundry with antimicrobial treatment every time it is washed. For example, Japanese Utility Model Application Laid-Open No. H5-74487 discloses an electric washing machine equipped with an ion generator that generates metal ions, such as silver or copper ions, that exert a sterilizing effect. Japanese Patent Application Laid-Open No. 2000-93691 discloses a washing machine that 20 sterilizes washing fluid by applying an electric field thereto. Japanese Patent Application Laid-Open No. 2001-276484 discloses a washing machine furnished with a silver ion adder unit that adds silver ions to washing fluid.

Moreover, as an example of which the use is not limited to washing machines, a sterilizing purifier that purifies water by the action of ions is disclosed in Japanese Utility

Model Application Laid-Open No. S63-126099.

In the washing machine disclosed in Japanese Patent Application Laid-Open No. 2001-276484 mentioned above, laundry is made antimicrobial by adding silver ions to water so that the silver ion concentration is 3 ppb to 50 ppb. In the design of modern washing machines, however, priority is given to how much laundry can be washed at a time, resulting in a tendency to reduce the water-to-laundry ratio (the ratio of the amount of water to the amount of laundry) with a view to maximizing the load (the amount of laundry) that can be handled at a time. Now, when the maximum amount of laundry is put in a washing machine, a silver ion concentration of 3 ppb to 50 ppb is, disadvantageously, no longer sufficient to treat all the laundry with antimicrobial treatment.

Disclosure of the invention

An object of the present invention is to provide a washing machine that, when treating laundry with antimicrobial treatment using metal ions, can treat the laundry with a concentration of metal ions that is commensurate with the amount of laundry. Another object of the present invention is to provide a washing machine that permits metal ions to exert their antimicrobial effect fully.

To achieve the above objects, according to the present invention, a washing machine is constructed as follows. In a washing machine that has electrodes formed of a metal that when ionized exerts an antimicrobial effect, that adds to water metal ions having an antimicrobial effect that are eluted from the electrodes when a voltage is applied therebetween, and that uses the water with the quantity of metal ions therein so adjusted as to be commensurate with the amount of laundry, the quantity of metal ions eluted is adjusted by varying the amount of electricity (the current multiplied by the voltage application duration) passed between the electrodes. With this construction, the amount of electricity can be adjusted easily.

According to the present invention, in the washing machine constructed as described above, the amount of electricity is varied, while the output voltage of the constant current circuit is so varied as to keep constant the current passed between the electrodes, by varying the voltage application duration. With this construction, the amount of electricity can be adjusted easily.

Alternatively, according to the present invention, a washing machine is constructed as follows. In a washing machine that has electrodes formed of a metal that when ionized exerts an antimicrobial effect, that adds to water metal ions having an antimicrobial effect that are eluted from the electrodes when a voltage is applied therebetween, and that uses the water with quantity of metal ions therein so adjusted as to be commensurate with amount of laundry, the quantity of metal ions is made commensurate with the amount of supplied water. With this construction, even a large amount of laundry can be made sufficiently antimicrobial. Thus, this construction is very suitable for a washing machine structure that is given a low water-to-laundry ratio and that is designed to be capable of handling a high maximum load.

Alternatively, according to the present invention, a washing machine is constructed as follows. In a washing machine that has electrodes formed of a metal that when ionized exerts an antimicrobial effect and that adds to water metal ions having an antimicrobial effect that are eluted from the electrodes when a voltage is applied therebetween, there are provided an electrode drive circuit that drives the electrodes and a constant current circuit that feeds a constant current between the electrodes irrespective of variation in the resistance between the electrode. With this construction, even when a variation in the resistance within the electrode drive circuit, in particular a variation in the resistance of the electrodes, causes the current flowing between the electrodes to reduce or a similar situation occurs, the constant current circuit raises its output voltage to prevent the decrease in the current.

Brief description of drawings

Fig. 1 is a vertical sectional view showing a washing machine embodying the invention.

Fig. 2 is a schematic vertical sectional view showing a water feed port.

5 Fig. 3 is a flow chart of an entire washing procedure.

Fig. 4 is a flow chart of a washing process.

Fig. 5 is a flow chart of a rinsing process.

Fig. 6 is a flow chart of a spin-drying process.

Fig. 7 is a schematic horizontal sectional view of an ion elution unit.

10 Fig. 8 is a schematic vertical sectional view of the ion elution unit.

Fig. 9 is a circuit diagram of a drive circuit for driving the ion elution unit.

Fig. 10 is a first flow chart showing a sequence for adding metal ions.

Fig. 11 is a table showing examples of experiments performed to make the set amount of water and the quantity of silver ions proportional to each other.

15 Fig. 12 is a table showing examples of experiments performed to study the effect of the silver ion concentration on the antimicrobial effect.

Fig. 13 is a table showing examples of experiments performed to study the effect of the duration for which laundry is kept dipped in water containing silver ions on the antimicrobial effect.

20 Fig. 14 is a graph showing the results of the experiments shown in Fig. 13.

Fig. 15 is a second flow chart showing the sequence for adding metal ions.

Best mode for carrying out the invention

Hereinafter, embodiments of the present invention will be described with reference to

Figs. 1 to 15.

Fig. 1 is a vertical sectional view showing the overall construction of a washing machine 1. The washing machine 1 is of a full-automatic type, and has a cabinet 10. The cabinet 10 is box-shaped, is formed of a metal or synthetic resin, and has openings in the top and bottom faces thereof. The top opening of the cabinet 10 is covered with a top plate 11, which is made of a synthetic resin and is fixed to the cabinet 10 with screws. In Fig. 1, the front and rear faces of the washing machine 1 are shown on the left and right, respectively. The top surface of a rear portion of the top plate 11 is covered with a back panel 12, which is formed of a synthetic resin and is fixed to the cabinet or the top plate 11 with screws. The bottom opening of the cabinet 10 is covered with a base 13, which is formed of a synthetic resin and is fixed to the cabinet 10 with screws. None of the screws thus far mentioned is shown in the figure.

In the four corners of the base 13, feet 14a and 14b are provided for supporting the cabinet 10 on a floor. The rear feet 14b are fixed feet that are formed integrally with the base 13. The front feet 14a are screw feet of which the supporting level can be adjusted; rotating these permits the washing machine 1 to be leveled.

In the top plate 11, a laundry inlet 15 is formed through which to put laundry into a washing tub, which will be described later. The laundry inlet 15 is covered with a lid 16 from above. The lid 16 is coupled to the top plate 11 with a hinge 14 so as to be pivotable in a vertical plane.

Inside the cabinet 10, a water tub 20 and a washing tub 30 are arranged, the latter also serving as a spin-drying tub. The water tub 20 and the washing tub 30 both have the shape of a cylindrical cup, and are arranged concentrically with the water tub 20 outside and the washing tub 30 inside. The water tub 20 is suspended from four inner corners of the cabinet

10 by four suspension members 21 that couple a bottom portion of the outer surface of the water tub 20 to those four inner corners of the cabinet 10. The water tub 20 is thus supported so as to be swingable in a horizontal plane.

The washing tub 30 has a circumferential wall that is so tapered as to gradually widen
5 upward. Except a plurality of water drain holes 31 formed in a ring-shaped pattern around a topmost portion of the washing tub 30, the washing tub 30 has no holes formed therein through which liquid can pass. That is, the washing tub 30 is of a so-called "holeless" type. Around the rim of the top opening of the washing tub 30, a ring-shaped balancer 32 is fitted
10 spin-drying of laundry. On the inner bottom surface of the washing tub 30, a pulsator 33 is arranged for producing a current in washing or rinsing water inside the tub.

On the bottom surface of the water tub 20, a drive unit 40 is mounted. The drive unit 40 includes a motor 41, a clutch mechanism 42, and a brake mechanism 43. From a central portion of the drive unit 40, a spin-drying spindle 44 and a pulsator spindle 45 extend upward.
15 The spin-drying spindle 44 and the pulsator spindle 45 are arranged with the former placed outside the latter, forming a double-axis structure. These spindles penetrate the water tub 20, inside which the spin-drying spindle 44 is coupled to the washing tub 30 so as to support it. The pulsator spindle 45 further penetrates the washing tub 30, inside which it is coupled to the pulsator 33 so as to support it. Between the spin-drying spindle 44 and the water tub 20, and
20 between the spin-drying spindle 44 and the pulsator spindle 45, sealing members are arranged to prevent the leakage of water.

In a space beneath the back panel 12, a water feed valve 50 is arranged that is electromagnetically opened and closed. The water feed valve 50 has a connection pipe 51 that penetrates the back panel 12 and extends upward. To the connection pipe 51, a water

feed hose (not illustrated) is connected through which clean water such as tap water is supplied. From the water feed valve 50, a water feed pipe 52 extends. The other end of the water feed pipe 52 is connected to a water feed port 53 formed in the shape of a container. The water feed port 53 is so located as to face the interior of the washing tub 30, and is
5 structured as shown in Fig. 2.

Fig. 2 is a schematic vertical sectional view of the water feed port 53, showing it as seen from in front. The water feed port 53 is open at the top face thereof, and has the interior thereof divided into a left-hand and a right-hand section. The left-hand section is a detergent chamber 54 where detergent is stored in preparation. The right-hand section is a
10 treatment agent chamber 55 where a treatment agent for washing is stored in preparation. In a front bottom portion of the detergent chamber 54, a horizontally elongate water outlet 56 is formed through which water is fed into the washing tub 30. In the treatment agent chamber 55, a siphon 57 is provided.

The siphon 57 is composed of an inner pipe 57a that rises upright from the bottom
15 surface of the treatment agent chamber 55 and a cap-shaped outer pipe 57b that is fitted around the inner pipe 57a. Between the inner pipe 57a and the outer pipe 57b, a gap is secured through which water can pass. The inner pipe 57a is, at the bottom end thereof, open toward the interior of the washing tub 30. Between the bottom end of the outer pipe 57b and the bottom surface of the treatment agent chamber 55, a predetermined gap is secured
20 so as to serve as an entrance for water. When water is poured into the treatment agent chamber 55 to a level higher than the top end of the inner pipe 57a, on the principle of a siphon, the water is sucked out of the treatment agent chamber 55 through the siphon 57 and falls into the washing tub 30.

The water feed valve 50 is composed of a main water feed valve 50a and a sub water

feed valve 50b. The connection pipe 51 is common to the main and sub water feed valves 50a and 50b. Correspondingly, the water feed pipe 52 is composed of a main water feed pipe 52a connected to the main water feed valve 50a and a sub water feed pipe 52b connected to the sub water feed valve 50b.

5 The main water feed pipe 52a is connected to the detergent chamber 54, and the sub water feed pipe 52b is connected to the treatment agent chamber 55. That is, the route by way of which water is fed from the main water feed pipe 52a through the detergent chamber 54 into the washing tub 30 is separate from the route by way of which water is fed from the sub water feed pipe 52b through the treatment agent chamber 55 into the washing tub 30.

10 Back in Fig. 1, to a bottom portion of the water tub 20, a water drain hose 60 is fitted through which to drain the water inside the water tub 20 and the washing tub 30 out of the cabinet 10. Water flows into the water drain hose 60 from water drain pipes 61 and 62. The water drain pipe 61 is connected to a portion of the floor surface of the water tub 20 near the circumference thereof. The water drain pipe 62 is connected to a portion of the floor
15 surface of the water tub 20 near the center thereof.

On the inner bottom surface of the water tub 20, a ring-shaped partition wall 63 is fixed so as to enclose the portion where the water drain pipe 62 is connected. In a top portion of the partition wall 63, a ring-shaped sealing member 64 is fitted. This sealing member 64 makes contact with the circumferential surface of a disk 65 fixed on the outer
20 bottom surface of the washing tub 30, and thereby forms a separate water drainage space 66 between the water tub 20 and the washing tub 30. The water drainage space 66 connects to the interior of the washing tub 30 through a water drain hole 67 formed in a bottom portion of the washing tub 30.

The water drain pipe 62 is fitted with a water drain valve 68 that is electromagnetically

opened and closed. In a portion of the water drain pipe 62 on the upstream side of the water drain valve 68, an air trap 69 is provided. From the air trap 69, a lead pipe 70 extends. To the top end of the lead pipe 70, a water level switch 71 is connected.

In a front portion of the cabinet 10, a control section 80 is arranged. The control section 80 is located beneath the top plate 11. The control section 80 receives operation instructions from the user through an operation/display section 81 provided on the top surface of the top plate 11, and feeds operation commands to the drive unit 40, the water feed valve 50, and the water drain valve 68. The control section 80 also feeds display commands to the operation/display section 81. The control section 80 includes a drive circuit for an ion elution unit, which will be described later.

Now, how the washing machine 1 operates will be described. The lid 16 is opened, and laundry is put in the washing tub 30 through the laundry inlet 15. Detergent is put in the detergent chamber 54 of the water feed port 53. As necessary, a treatment agent is put in the treatment agent chamber 55 of the water feed port 53. The treatment agent may be put in during the course of a washing procedure.

After the detergent is made ready to be added, the lid 16 is closed, and the operation buttons provided on the operation/display section 81 are operated to select desired washing conditions. When a start button is pressed finally, a washing procedure is performed according to the flow charts shown in Figs. 3 to 6.

Fig. 3 is a flow chart showing the entire washing procedure. In step S201, whether or not reserved operation, which permits washing to be started at a specified time, is selected is checked. If reserved operation is selected, then the operation flow proceeds to step S202; if not, the operation flow proceeds to step S202.

In step S206, whether or not the operation start time has been reached is checked. If

the operation start time has been reached, the operation flow proceeds to step S202.

In step S202, whether or not a washing process is selected is checked. If a washing process is selected, the operation flow proceeds to step S300. The operations performed in the washing process in step S300 will be described in detail later with reference to the flow chart shown in Fig. 4. After the completion of the washing process, the operation flow proceeds to step S203. If no washing process is selected, the operation flow proceeds directly from step S202 to step S203.

In step S203, whether or not a rinsing process is selected is checked. If a rinsing process is selected, the operation flow proceeds to step S400. The operations performed in the rinsing process in step S400 will be described in detail later with reference to the flow chart shown in Fig. 5. After the completion of the rinsing process, the operation flow proceeds to step S204. If no rinsing process is selected, the operation flow proceeds directly from step S203 to step S204.

In step S204, whether or not a spin-drying process is selected is checked. If a spin-drying process is selected, the operation flow proceeds to step S500. The operations performed in the spin-drying process in step S500 will be described in detail later with reference to the flow chart shown in Fig. 6. After the completion of the spin-drying process, the operation flow proceeds to step S205. If no spin-drying process is selected, the operation flow proceeds directly from step S204 to step S205.

In step S205, the operations for terminating the control section 80, in particular the operation processor (microcomputer) included therein, are automatically performed through a predetermined sequence. Moreover, the completion of the washing procedure is indicated by sounding a completion alert. On completion of all the necessary operations, the washing machine 1 is brought back into a stand-by state so as to be ready for another washing

procedure.

Next, with reference to Figs. 4 to 6, the operations performed in each of the washing, rinsing, and spin-drying processes will be described.

Fig. 4 is a flow chart of the washing process. In step S301, the water level inside the washing tub 30 as detected by the water level switch 71 is read out. In step S302, whether or not laundry amount sensing is selected is checked. If laundry amount sensing is selected, the operation flow proceeds to step S308; if not, the operation flow proceeds directly from step S302 to step S303.

In step S308, based on the rotation load of the pulsator 33, the amount of the laundry is measured. After the laundry amount sensing, the operation flow proceeds to step S303.

In step S303, the main water feed valve 50a is opened so that water is fed through the main water feed pipe 52a and the water feed port 53 into the washing tub 30. Here, the detergent put in the detergent chamber 54 of the water feed port 53 is mixed with the water and is fed into the washing tub 30. The water drain valve 68 remains closed. When the water level switch 71 detects the set water level, the main water feed valve 50a is closed. The operation flow then proceeds to step S304.

In step S304, familiarizing is performed. The pulsator 33 rotates alternately in the forward and backward directions to agitate the laundry and water so as to familiarize the laundry with the water. This permits the laundry to absorb an ample amount of water, and also permits the air trapped in different parts of the laundry to escape. If, as a result of the familiarizing, the water level detected by the water level switch 71 has become lower than it originally was, then, in step S305, the main water feed valve 50a is opened to feed supplemental water to restore the set water level.

If a washing course including "cloth type sensing" is selected, when the familiarizing

is performed, cloth type sensing is also performed. After the familiarizing is performed, the change in the water level from the set water level is detected, and, if the drop in the water level is greater than a predetermined value, the cloth type is judged to be highly water-absorbent.

- 5 After the set water level is stably obtained in step S305, the operation flow proceeds to step S306. According to the settings made by the user, the motor 41 rotates the pulsator 33 in a predetermined pattern so as to produce a main water current for washing inside the washing tub 30. With this main water current, the laundry is washed. The spin-drying spindle 44 remains braked by the brake mechanism 43, and thus, even when the washing
- 10 water and laundry move, the washing tub 30 does not rotate.

After the period of the main water current, the operation flow proceeds to step S307. In step S307, the pulsator 33 rotates alternately in the forward and backward directions in quick steps to loosen the laundry so that the laundry is evenly spread inside the washing tub 30. This is done in preparation for the spin-drying rotation of the washing tub 30.

- 15 Next, with reference to the flow chart shown in Fig. 5, the operations performed in the rinsing process will be described. First, in step S500, a spin-drying process is performed, which will be described later with reference to the flow chart shown in Fig. 6. After the spin-drying, the operation flow proceeds to step S401. In step S401, the main water feed valve 50a is opened, and water is fed up to the set water level.

- 20 After the feeding of water, the operation flow proceeds to step S402. In step S402, familiarizing is performed. In the familiarizing in step S402, the laundry that has stuck to the washing tub 30 in step S500 (spin-drying process) is removed therefrom, is familiarized with water, and is made to absorb an ample amount of water.

After the familiarizing, the operation flow proceeds to step S403. If, as a result of the

familiarizing, the water level as detected by the water level switch 71 has become lower than it originally was, the main water feed valve 50a is opened to feed supplemental water to restore the set water level.

After the set water level is restored in step S403, the familiarizing proceeds to step
5 S404. According to the settings made by the user, the motor 41 rotates the pulsator 33 in a predetermined pattern to produce a main water current for rinsing inside the washing tub 30. With this main water current, the laundry is rinsed. The spin-drying spindle 44 remains braked by the brake mechanism 43, and thus, even when the rinsing water and laundry move, the washing tub 30 does not rotate.

10 After the period of the main water current, the operation flow proceeds to step S405. In step S405, the pulsator 33 rotates alternately in the forward and backward directions in quick steps to loosen the laundry. This permits the laundry to be evenly spread inside the washing tub 30 in preparation for spin-drying rotation.

In the above description, rinsing is performed as "stored-water rinsing" whereby
15 rinsing is performed with rinsing water stored in the washing tub 30. It is, however, also possible to perform rinsing as "supplied-water rinsing" whereby rinsing is performed while fresh water is kept being supplied, or as "shower rinsing" whereby, while the washing tub 30 is rotated at low speed, water is sprayed from the water feed port 53 onto the laundry.

Next, with reference to the flow chart shown in Fig. 6, the operations performed in the
20 spin-drying process will be described. First, in step S501, the water drain valve 68 is opened. The washing water inside the washing tub 30 is drained through the water drainage space 66. During the spin-drying process, the water drain valve 68 remains open.

When most of the washing water contained in the laundry has been drained, the clutch mechanism 42 and the brake mechanism 43 are switched. The clutch mechanism 42 and the

brake mechanism 43 may be switched before the start of the draining or at the same time as the draining. The motor 41 now rotates the spin-drying spindle 44. Thus, the washing tub 30 performs spin-drying rotation. The pulsator 33 rotates along with the washing tub 30.

As the washing tub 30 rotates at high speed, the laundry is pressed onto the interior circumferential wall of the washing tub 30 under centrifugal force. Thus, the washing water contained in the laundry collects on the interior surface of the circumferential wall of the washing tub 30. At this time, since the washing tub 30 is so tapered as to gradually widen upward as described earlier, the washing water acted upon by the centrifugal force rises along the interior surface of the washing tub 30. When the washing water reaches the upper end of the washing tub 30, it is discharged through the drain holes 31. After leaving the drain holes 31, the washing water hits the interior surface of the water tub 20, and then flows along the interior surface of the water tub 20 to the bottom of the water tub 20. Then, the washing water is discharged out of the cabinet 10 via the water drain pipe 61 and the water drain hose 60 connected thereto.

In the operation flow shown in Fig. 6, first spin-drying is performed at relatively low speed in step S502, and then spin-drying is performed at high speed in step S503. After step S503, the operation flow proceeds to step S504. In step S504, the supply of electric power to the motor 41 is stopped, and the terminating operations are performed.

The washing machine 1 is provided with an ion elution unit 100. The ion elution unit 100 is provided in the middle of the main water feed pipe 52a, specifically between the main water feed valve 50a and the detergent chamber 54. Depending on the specifications of the actual product, the ion elution unit 100 may be provided in the middle of the sub water feed pipe 52b, specifically between the 50b and the treatment agent chamber 55. Hereinafter, with reference to Figs. 7 to 15, the structure and function of the ion elution unit 100 and the

role it plays when mounted on the washing machine 1 will be described.

Figs. 7 and 8 are schematic sectional views showing a first embodiment of the ion elution unit 100, Fig. 7 being a horizontal sectional view thereof and Fig. 8 a vertical sectional view. The ion elution unit 100 has a case 110 formed of an insulating material such as synthetic resin, silicone, or rubber. The ion elution unit 100 has a water inflow port 111 at one end thereof and a water outflow port 112 at the other end thereof. Inside the case 110, two plate-shaped electrodes 113 and 114 are arranged parallel to and at a predetermined interval from each other. The electrodes 113 and 114 are formed of a metal, such as silver, copper, or zinc, that yields metal ions that exert an antimicrobial effect.

The electrodes 113 and 114 are, at one ends thereof, respectively provided with terminals 115 and 116. Ideally, the electrode 113 and the terminal 115 are integrally formed, and so are the electrode 114 and the terminal 116. Where this is impossible, the joints between the electrodes and the terminals and the parts of the terminals located inside the case 110 are coated with synthetic resin so as to be out of contact with water and thus free from electrolytic corrosion. The terminals 115 and 116 protrude out of the case 110, and are connected to the drive circuit provided in the control section 80.

Inside the case 110, water flows parallel to the length direction of the electrodes 113 and 114. With water present inside the case 110, when a predetermined voltage is applied between the electrodes 113 and 114, from whichever of the electrodes 113 and 114 is on the positive side, metal ions of the ion of which those electrodes are formed are eluted. The electrodes 113 and 114 are, for example, silver plates each measuring 2 cm wide, 5 cm long, and 1 mm thick, and are arranged at an interval of 5 mm from each other. Where silver electrodes are used, at whichever of them is on the positive side, the reaction $\text{Ag} \rightarrow \text{Ag}^+ + \text{e}^-$ occurs, eluting silver ions Ag^+ into water.

To prevent water from remaining inside the case 110 after the completion of the feeding of metal ions, it is advisable to slant the bottom surface of the cabinet 10 so that it is increasingly low toward the downstream side.

Fig. 9 shows the drive circuit 120 of the ion elution unit 100. A transformer 122 is
5 connected to commercially distributed electric power 121 to step down the voltage thereof, i.e., 100 V, to a predetermined voltage. The output voltage of the transformer 122 is rectified by a full-wave rectifier circuit 123, and is then regulated into a constant voltage by a constant voltage circuit 124. To the constant voltage circuit 124, a constant current circuit
10 125 is connected. The constant current circuit 125 so operates that an electrode drive circuit 150, which will be described later, is always fed with a constant current irrespective of variations in the resistance across the electrode drive circuit 150.

To the commercially distributed electric power 121, a rectifying diode 126 is connected in parallel with the transformer 122,. The output voltage of the rectifying diode 126 is smoothed by a capacitor 127, is then regulated into a constant voltage by a constant
15 voltage circuit 128, and is then fed to a microcomputer 130. The microcomputer 130 controls the starting of a triac 129 that is connected between one end of the primary coil of the transformer 122 and the commercially distributed electric power 121.

The electrode drive circuit 150 is built with NPN-type transistors Q1 to Q4, diodes D1 and D2, and resistors R1 to R7, and these are interconnected as shown in the figure. The
20 transistor Q1 and the diode D1 together form a photocoupler 151, and the transistor Q2 and the diode D2 together form a photocoupler 152. That is, the diodes D1 and D2 are photodiodes, and the transistors Q1 and Q2 are phototransistors.

When the microcomputer 130 feeds a high-level voltage to a line L1 and a low-level voltage (or a zero voltage) to a line L2, the diode D2 turns on, and accordingly the transistor

Q2 turns on. When the transistor Q2 turns on, a current flows through the resistors R3, R4, and R7, and thus the base of the transistor Q3 is biased, causing this transistor Q3 to turn on.

On the other hand, since the diode D1 is off, the transistor Q1 is off, and accordingly the transistor Q4 also is off. In this state, a current flows from the positive-side electrode 113 to the negative-side electrode 114. Thus, within the ion elution unit 100, metal ions as positive ions are produced along with negative ions.

When a current is passed through the ion elution unit 100 in one direction for a long time, whereas the electrode 113 on the positive side in Fig. 9 wears off, impurities such as calcium present in water deposit in the form of scale on the electrode 114 on the negative side. Moreover, the chloride and sulfide of the ingredient metal of the electrodes form on the surface thereof. This degrades the performance of the ion elution unit 100. To prevent this, the electrode drive circuit 150 is so configured that it can be operated also with the polarities of the electrodes reversed.

To reverse the polarities of the electrodes, the microcomputer 130 switches its control so as to reverse the voltages fed to the lines L1 and L2 so that a current flows in the opposite direction between the electrodes 113 and 114. Now, the transistors Q1 and Q4 are on, and the transistors Q2 and Q3 are off. The microcomputer 130 incorporates a counter function, and performs this switching every time a predetermined count is reached.

If, as a result of a variation in the resistance across the electrode drive circuit 150, in particular in the resistances of the electrodes 113 and 114, the current flowing between the electrodes decreases or a similar situation occurs, the constant current circuit 125 raises the output voltage thereof to prevent a decrease in the current. However, as the accumulated use time increases, the water treatment unit 100 ultimately reaches the end of the useful life thereof. When this happens, it is no longer possible to prevent a decrease in the current even

by switching to an electrode cleaning mode for forcibly removing the impurities deposited on the electrodes by reversing their polarities or by keeping them at particular polarities for a longer time than usual, or even by raising the output voltage of the constant current circuit 125.

5 To cope with this, in the circuit under discussion, the current flowing between the electrodes 113 and 114 of the ion elution unit 100 is monitored by monitoring the voltage across the resistor R7, and, when this current becomes equal to the minimum permissible current level, it is detected by a current detecting means. A current detection circuit 160 serves as the current detecting means. The information that the minimum permissible
10 current level has been detected is fed from a photodiode D3 included in a photocoupler 163 via a phototransistor Q5 included in the same photocoupler 163 to the microcomputer 130. The microcomputer 130 then drives, via a line L3, an alert indicating means 131 to make it give out a predetermined warning indication. The alert indicating means 131 is provided in the operation/display section 81 or the control section 80.

15 Moreover, to cope with a fault such as a short circuit within the electrode drive circuit 150, a current detecting means is provided for detecting that the current has become higher than the maximum permissible current level. On the basis of the output of this current detecting means, the microcomputer 130 drives the alert indicating means 131. A current detection circuit 161 serves as the current detecting means. Likewise, when the output
20 voltage of the constant current circuit 125 becomes lower than a predetermined minimum level, a voltage detection circuit 162 detects it, and the microcomputer 130 drives the alert indicating means 131.

Fig. 10 is a flow chart showing the sequence for eluting and adding metal ions. The sequence shown in Fig. 10 is executed in the stage of step S401 (feed water) or step S403

(feed supplemental water) in the operation flow shown in Fig. 5. Specifically, when the rinsing is started, then, in step S411, whether or not addition of metal ions is selected is checked. This checking may be performed earlier. If "addition of metal ions" is selected through selection operation performed on the operation/display section 81, then the operation
5 flow proceeds to step S412; if not, the operation flow proceeds to step S414.

In step S412, the main water feed valve 50a is opened so that water is fed to the ion elution unit 100 at a predetermined flow rate. Simultaneously, the drive circuit 120 applies a voltage between the electrodes 113 and 114 so that ions of the metal of which they are formed are eluted into the water. The current that flows between the electrodes is a direct current.
10 The water containing the metal ions is fed through the water feed port 53 into the washing tub 30.

When a predetermined amount of water containing metal ions has been added and the concentration of the metal ions in the rinsing water is judged to have reached a predetermined level, the application of the voltage to the electrodes 113 and 114 is stopped, and, when water
15 is fed to the set water level, the main feed valve 50a is closed.

Next, in step S413, the rinsing water is agitated to promote contact between the laundry and the metal ions. The agitation is continued for a predetermined period of time.

Next, in step S414, whether or not addition of a treatment agent is selected is checked. This checking may be performed earlier; for example, it may be performed at the same time
20 as the checking, in step S411, of whether or not addition of metal ions is selected. If "addition of a treatment agent" is selected through selection operation performed on the operation/display section 81, then the operation flow proceeds to step S415; if not, the operation flow proceeds to step S405. In step S405, the pulsator 33 is rotated alternately in the forward and reverse directions in quick steps to make the laundry loose so that the laundry

is spread evenly inside the washing tub 30 in preparation for spin-drying rotation.

In step S415, the sub water feed valve 50b is opened so that water is passed through the treatment agent compartment 55 of the water feed port 53. If a treatment agent has been put in the treatment agent compartment 55, it is, along with the water, fed into the washing
5 tub 30 through the siphon 57. It is not before the water level inside the treatment agent compartment 55 reaches a predetermined height that the principle of siphon works. This makes it possible to keep a liquid treatment agent in the treatment agent compartment 55 until the time comes when water is poured into the treatment agent compartment 55.

When a predetermined amount of water (sufficient to cause the siphon 57 to work as a
10 siphon, or more) has been poured into the treatment agent compartment 55, the sub water feed valve 50b is closed. Incidentally, this feeding of water, i.e., the operation performed to add the treatment agent, is performed automatically irrespective of whether or not a treatment agent is put in the treatment agent compartment 55 so long as adding of a treatment agent is selected.

15 Next, in step S416, the rinsing water is agitated to promote contact between the laundry and the treatment agent. The agitation is continued for a predetermined period of time, and then the operation flow proceeds to step S405.

According to the sequence described above, it is a predetermined period of time after the metal ions are added to the rinsing water that the treatment agent is added to the rinsing
20 water. If the metal ions and the treatment agent (softening agent) are simultaneously added to the rinsing water, the metal ions react with the ingredients of the softening agent, resulting in a diminished antimicrobial effect. By contrast, according to the sequence described above, it is after the metal ions have sufficiently attached to the laundry that the treatment agent is added. This prevents the metal ions from reacting with the ingredients of the treatment agent,

and thus helps leave the antimicrobial effect exerted by the metal ions on the laundry.

The metal of which the electrodes 113 and 114 are formed is selected from among, in addition to silver, copper, silver-copper alloy, and zinc, for example. Silver ions eluted from a silver electrode, copper ions eluted from a copper electrode, and zinc ions eluted from a zinc
5 electrode exert an excellent antimicrobial or antifungal effect. Silver-copper alloy permits silver and copper ions to be eluted simultaneously therefrom.

Silver ions are positive ions. In water, laundry is negatively charged, and therefore silver ions are electrically attracted by laundry. Once silver ions attach to laundry, they are electrically neutralized. This makes the silver ions less likely to react with the chloride ions
10 (negative ions) contained in a treatment agent (softening agent). Here, it takes time for the silver ions to attach to the laundry, and this makes it necessary to wait for a certain period of time before adding the treatment agent. Accordingly, after the silver ions are added, agitation is performed for 5 minutes or more. After the addition of the treatment agent, it suffices to perform agitation for about three minutes.

15 The metal ions are fed into the washing tub 30 through the main feed pipe 52a and then through the detergent compartment 54. The treatment agent is fed into the washing tub 30 through the treatment agent compartment 55. Thus, the route by way of which the metal ions are added to the rinsing water is separate from the route by way of which the treatment agent is added to the rinsing water. This prevents the metal ions from passing through the
20 route through which the treatment agent is added to the rinsing water, thus prevents them from making contact with the treatment agent remaining on the route, and thus prevents them from forming compounds therewith and losing their antimicrobial effect.

Moreover, according to the sequence described above, the addition of the metal ions and the addition of the treatment agent are each accompanied by the agitation of the rinsing

water. This ensures that the metal ions and the treatment agent attach to all parts of the laundry.

According to the present invention, to treat laundry with effective antimicrobial treatment by the action of metal ions, the washing machine 1 is operated under the conditions
5 described below.

<Condition 1>

The first condition relates to the quantity of metal ions. The quantity of metal ions is made commensurate with the amount of laundry. In the flow chart of the washing process
10 shown in Fig. 4, in step S308, laundry amount sensing is performed. Based on the amount of laundry grasped as a result of the laundry amount sensing, the amount of water fed into the washing tub 30 in the washing and rinsing processes is determined. Then, metal ions are eluted in a quantity proportional to the thus determined amount of water.

The table in Fig. 11 shows examples of experiments in which silver ions were eluted
15 in such a way as to fulfill condition 1 above. The set amount of rinsing water was varied in the following three steps: 23 L, 35 L, and 46 L. The quantity of electricity (current multiplied by the duration of voltage application) that is passed between the electrodes 113 and 114 was made proportional to the set amount of rinsing water. As a result, with any of the different set amounts of rinsing water, the concentration of silver ions was 90 ppb. This
20 indicates that a quantity of silver ions that is proportional to the set amount of water was eluted. The set amount of water is determined based on the amount of laundry, and hence the quantity of silver ions eluted can be said to be commensurate with the amount of laundry. In this way, when a large amount of laundry is dealt with, by increasing the quantity of metal ions, it is possible to obtain an antimicrobial effect comparable to that obtained when a small

amount of laundry is dealt with.

In a case where, for higher laundry amount sensing, the set amount of water is varied in more than three steps, the amount of electricity that is passed between the electrodes 113 and 114 is varied accordingly in as many steps. By adjusting one or both of the current and
5 the voltage application duration, the amount of electricity can be adjusted easily.

The method described above whereby the quantity of metal ions eluted is adjusted based on the sensed amount of laundry is one way (first method) of making the quantity of metal ions added to water commensurate with the amount of laundry. There are other ways to achieve the same end, as will be described below.

10 According to a second method, instead of relying on laundry amount sensing, the user him or herself determines the amount of laundry by measuring it with scales or by the eye, and then determines, according to the thus determined amount of laundry, the amount of electricity that is passed between the electrodes 113 and 114. For example, the user is permitted to select an appropriate choice among several different weight classes to determine
15 the amount of electricity.

According to a third method, the amount of electricity that is passed between the electrodes 113 and 114 is determined based on the maximum capacity (the upper limit of the amount of laundry that can be washed) of the washing machine 1, and the thus determined amount of electricity is applied in all cases. The maximum capacity is specific to each
20 washing machine model. Thus, eluting a quantity of metal ions commensurate with the maximum capacity is nothing other than making the quantity of metal ions commensurate with the amount of laundry with the maximum capacity regarded as an invariable parameter.

By this method, a quantity of metal ions commensurate with the maximum capacity is supplied in all cases. This helps prevent the quantity of supplied metal ions from becoming

too small as a result of the amount of laundry being underestimated due to an error in laundry amount sensing or in measurement performed with scales or by the eye.

<Condition 2>

- 5 The second condition relates to the type of metal and the concentration of metal ions. Silver is selected as the metal, and water with a silver ion concentration of 50 ppb or more is used for rinsing.

 The table in Fig. 12 shows examples of experiments performed to study the effect of the silver ion concentration on the antimicrobial effect. The experiments were performed by actually using a washing machine, and how antimicrobial and deodorant a cloth was made as
10 evaluated after drying was evaluated according to JIS (Japanese Industrial Standards) L1902 (directed to the testing of the antimicrobial properties of textile products). A standard cloth was contaminated with *Staphylococci aurei* so that the initial number of bacteria was 1.2×10^5 / ml, and, after a 18-hour culture, the number of bacteria was measured again. The result
15 was 1.9×10^7 / ml. 8 kg of laundry was rinsed in water with a silver ion concentration of 50 ppb for 10 minutes, was then spin-dried and dried, and then a similar experiment was performed. The number of remaining bacteria was 2.4×10^6 / ml. The antimicrobial efficacy value (the difference in the increase or decrease in the number of bacteria as calculated in logarithmic terms relative to the standard cloth) was 0.9. This value needs to
20 be 2.0 or more to be recognized as satisfactorily antimicrobial and deodorant. Thus, rinsing 8 kg of laundry in water with a silver ion concentration of 50 ppb does not yield a significant antimicrobial effect.

 Next, 8 kg of laundry was contaminated with *Staphylococci aurei* so that the initial number of bacteria was 1.2×10^5 / ml, was then rinsed for 10 minutes in water with a silver

ion concentration of 90 ppb, was then spin-dried and dried, and then a similar experiment was performed. The number of remaining bacteria was 2.5×10^4 / ml. The antimicrobial efficacy value was thus 2.9, indicating that the laundry was made satisfactorily antimicrobial and deodorant. That is, with a silver ion concentration of 50 to 100 ppb, it is possible to
5 make laundry necessarily and sufficiently antimicrobial and deodorant.

Further increasing the silver ion concentration enhances the antimicrobial effect accordingly. However, with too high a silver ion concentration in water, when laundry is dried, silver is visibly deposited on the surface of the laundry. Through oxidation and sulfuration, the deposited silver turns black, forming black stains on the laundry. Thus, in
10 practical terms, there exists an upper limit for the silver ion concentration in the water used in the antimicrobial treatment of laundry.

Performing rinsing repeatedly using water with a silver ion concentration of 900 ppb gave the following results. With rinsing performed three times, no change was observed in the appearance of laundry. With rinsing performed five times, however, the reflectivity of
15 laundry as measured after drying in the sun was 3 % lower than before rinsing. This degree of lowering in reflectivity is difficult to recognize with the eye. However, lowering of reflectivity may become recognizable in white articles of laundry, in which lowering of reflectivity (blackening) is inherently easy to recognize, and in articles of laundry that are not necessarily white but in which lowering of reflectivity has occurred accumulatively due to
20 repeated washing. Thus, the practical upper limit of the silver ion concentration is believed to be about 900 ppb.

The control performed to obtain a silver ion concentration of 50 ppb or more may be performed with the value of 50 ppb set as the lower limit targeted by the control. To allow for measurement errors, however, a certain margin may be secured with respect to the

targeted value. Specifically, it is practical and preferable to set the lower limit targeted by the control at about 51 to 55 ppb.

<Condition 3>

5 The third condition relates to the duration for which laundry is kept in contact with water with a silver ion concentration of 50 ppb or more. The operation program is so set that laundry is kept dipped in water with a silver ion concentration of 50 ppb or more for five minutes or more.

10 The table in Fig. 13 and the graph in Fig. 14 show examples of experiments performed to study the effect of the duration for which laundry is kept in contact with washing and rinsing water on the antimicrobial effect. Laundry was kept dipped in rinsing water with a silver ion concentration of 90 ppb, and then the antimicrobial efficacy value was determined. When the dip duration was five minutes or more, an antimicrobial efficacy value sufficiently high to be recognized as exerting an antimicrobial effect was obtained. When the dip
15 duration was four minutes, the antimicrobial efficacy value was 1.7, indicating that no recognizable antimicrobial or deodorant effect was obtained.

<Condition 4>

20 The fourth condition relates to how laundry is kept in contact with water with a silver ion concentration of 50 ppb or higher. At an early stage of contact, an agitation process is performed that lasts for a predetermined period of time, and then a standstill process is performed that lasts for the same predetermined period of time.

Fig. 15 is a flow chart showing a modified version of the sequence for adding metal ions shown in Fig. 10, the modification being the addition thereto of the standstill process just

mentioned. After the agitation process in step S413, a standstill process is performed in step S430. Specifically, rinsing water is agitated so that every corner of laundry is kept in contact with rinsing water with a silver ion concentration of 50 ppb or more (in this case, 50 ppb to 100 ppb), and then the laundry and water are kept still for a while. Here, these are not necessarily kept perfectly still, but the pulsator 33 may be moved slowly from time to time to keep the user aware that a washing procedure is still underway.

Silver ions are absorbed by laundry over time irrespective of whether the water that contains them is moving or not. Thus, first agitating water so that silver ions spread to every corner of laundry permits the silver ions to attach to the laundry even when the water is thereafter kept still. By waiting for silver ions to attach to laundry in a still-standing state in this way, it is possible to minimize the damage to the laundry. Here, in steps S413 and S430 altogether, laundry is kept in contact with water with a silver ion concentration of 50 ppb or more (in this case, 50 ppb to 100 ppb) for five minutes or longer.

15 <Condition 5>

The fifth condition relates to the intensity of agitation. When laundry is dipped in and agitated together with water with a silver ion concentration of 50 ppb or more, the intensity of agitation is adjusted according to the amount of laundry.

When a large amount of laundry is dealt with, the pulsator 33 is rotated at an increased rotation rate and for a longer period of time. When a small amount of laundry is dealt with, the pulsator 33 is rotated at a reduced rotation rate and for a shorter period of time. In this way, it is possible to produce in the laundry and rinsing water a current of which the intensity is always higher than a certain level irrespective of the amount of laundry. Thus, it is possible to spread silver ions to every corner of laundry.

Conditions 1 to 5 described above may be fulfilled at least singly and preferably in a combination of as many of them as possible.

It should be understood that the embodiments of the present invention specifically described above are not intended to limit the scope of the present invention in any way, and, 5 in implementing the present invention, many modifications and variations are possible within the spirit of the present invention.

For example, the ion elution unit 100 may be arranged elsewhere than between the water feed valve 50 and the water feed port 53; it may be arranged anywhere between the connection pipe 51 and the water feed port 53. That is, it may be placed on the upstream 10 side of the water feed valve 50. Placing the ion elution unit 100 on the upstream side of the water feed valve 50 permits the ion elution unit 100 to be kept dipped in water all the time. This prevents the sealing member from drying and deteriorating and thereby causing water leakage.

The ion elution unit 100 may be placed outside the cabinet 10. For example, the ion 15 elution unit 100 may be built in the form of a replaceable cartridge so as to be, for example, screwed into the connection pipe 51, with the water feed hose connected to the cartridge.

Regardless of whether or not it is built in the form of a replaceable cartridge or not, placing the ion elution unit 1 outside the cabinet 10 permits the ion elution unit 100 to be replaced without opening a door provided in a part of the washing machine 1 or removing a 20 panel thereof. This ensures easy maintenance. Moreover, the replacement can be performed without touching electrically charged components inside the washing machine 1. This ensures safety.

When the ion elution unit 100 is placed outside the cabinet 10 as described above, a cable extending from the drive circuit 120 is connected thereto through a water-resistant

connector so that the ion elution unit 100 is fed with an electric current. The feeding of electric power from the drive circuit 120, however, can be omitted when the ion elution unit 100 is driven with electricity fed from a battery. Alternatively, it may be driven with electric power generated by a hydraulic power generating apparatus having a hydraulic turbine
5 arranged in the flow of the supplied water.

The ion elution unit 100 may be sold as an independent product to promote the incorporation thereof into appliances other than washing machines.

It should be understood that the present invention find application not only in washing machines of the full automatic type, like the one dealt with in the embodiment described
10 above, but in all types of washing machines including those having a horizontal drum (of the tumbler type), those having a slanted drum, those that can be shared as a dryer, and those having two tubs.

Industrial applicability

15 As described above, according to the present invention, in a washing machine that uses water after adding to the water metal ions that exert an antimicrobial effect, the quantity of metal ions is adjusted to be commensurate with the amount of laundry. Thus, even a large amount of laundry can be made sufficiently antimicrobial. This construction is very suitable for a washing machine structure that is given a low water-to-laundry ratio and that is designed
20 to be capable of handling a high maximum load. Moreover, a metal that when ionized exerts an antimicrobial effect is formed into electrodes, and metal ions eluted from the electrodes when a voltage is applied therebetween are used. Thus, a necessary quantity of metal ions can be obtained on the spot. Moreover, silver is selected as the metal, and water with a silver ion concentration of 50 ppb or more is used. Thus, it is possible to make laundry

sufficiently antimicrobial even under high load, low water-to-laundry ratio conditions, and to surely obtain a deodorant effect. This helps further enhance the inherent aim of using a washing machine, specifically that of enhancing the hygiene of clothes, and thereby contributes to the enhancement of hygiene in civil life.

CLAIMS

1. A washing machine
that has electrodes formed of a metal that when ionized exerts an antimicrobial effect,
that adds to water metal ions having an antimicrobial effect that are eluted from the
electrodes when a voltage is applied therebetween, and
that uses the water with quantity of metal ions therein so adjusted as to be
commensurate with amount of laundry,
wherein the quantity of metal ions eluted is adjusted by varying amount of electricity
(current multiplied by voltage application duration) passed between the electrodes.
2. The washing machine of claim 1,
wherein the metal is silver, and a silver ion concentration in water is set at 50 ppb or
more.
3. The washing machine of claim 2,
wherein the silver ion concentration in water is set at 50 ppb to 100 ppb.
4. The washing machine of claim 2,
wherein the silver ion concentration in water is set at 50 ppb to 900 ppb.
5. The washing machine of one of claims 2 to 4,
wherein an operation program is so set that the laundry is kept in contact with the
water containing the aforementioned concentration of silver ions for five minutes or more.

6. The washing machine of one of claims 2 to 4,

wherein, when the water containing the aforementioned concentration of metal ions is made to make contact with laundry, first, at an initial stage of contact, an agitation process is performed that lasts for a predetermined period of time, and then, immediately thereafter, a standstill process is performed that lasts for a predetermined period of time.

7. The washing machine of one of claims 2 to 4,

wherein, while laundry is dipped and agitated in the water containing the aforementioned concentration of metal ions, intensity of agitation is adjusted according to amount of laundry.

8. A washing machine

that has electrodes formed of a metal that when ionized exerts an antimicrobial effect, that adds to water metal ions having an antimicrobial effect that are eluted from the electrodes when a voltage is applied therebetween, and

that uses the water with quantity of metal ions therein so adjusted as to be commensurate with amount of laundry,

wherein the washing machine includes an electrode drive circuit that drives the electrodes and a constant current circuit that feeds a constant current between the electrodes irrespective of variation in resistance between the electrode, and

wherein the quantity of metal ions eluted is adjusted by varying amount of electricity (current multiplied by voltage application duration) passed between the electrodes.

9. The washing machine of claim 8,

wherein the amount of electricity is varied, while an output voltage of the constant current circuit is so varied as to keep constant a current passed between the electrodes, by varying voltage application duration.

10. A washing machine

that has electrodes formed of a metal that when ionized exerts an antimicrobial effect, that adds to water metal ions having an antimicrobial effect that are eluted from the electrodes when a voltage is applied therebetween, and

that uses the water with quantity of metal ions therein so adjusted as to be commensurate with amount of laundry,

wherein the quantity of metal ions is made commensurate with amount of supplied water.

11. A washing machine

that has electrodes formed of a metal that when ionized exerts an antimicrobial effect, and

that adds to water metal ions having an antimicrobial effect that are eluted from the electrodes when a voltage is applied therebetween,

wherein there are provided an electrode drive circuit that drives the electrodes and a constant current circuit that feeds a constant current between the electrodes irrespective of variation in resistance between the electrode.